Recent advance in Pediatric Nuclear Medicine

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Discloses no relevant financial relationships with commercial interests.

Member, advisory board, OHS, Startup company
Outline

- Normal Distribution of FDG
- Oncology, Neurology, Cardiology
- New Agents
- UTI, MIBG, Salivagram, IBD
PATIENT PREPARATION

- NPO a minimum of 4hrs prior to injection
- Glucose <11mmol/L (150mg/dL) prior to $^{18}$F FDG injection
- Current height and weight is obtained
- Concise and thorough history including current meds, last chemotherapy or radiation therapy
Dose

- Recommended dose for pediatric whole body scan is 5-10 MBq/kg or 0.14-0.30mCi/kg
  - Minimum dose of 1mCi (37MBq)
  - Maximum dose of 10mCi used
- Pre and Post dose measurements are documented with patient information
If non diagnostic CT (low dose for attenuation correction only) required mAs in range of 16-30 (dependent on weight)

- Scans routinely done: Base skull-mid thigh
- Begin imaging 45 to 60 min after injection
- Acquisition 3 min per bed position
- Patient is asked to void prior to imaging
Normal Variant: *Thymus*

- Seen frequently in children
- Diffuse and homogenous
- Inverted V
- Correlate CT
- FDG uptake post therapy seen in 75% of children
Normal Variants

Head and Neck

- Tonsils
- Tongue and orophrynx
- Lymphatic tissue in Waldeyer’s ring
- Larynx
- Extraocular muscles
- Thyroid
- Salivary Gland
F18-FDG activity in neck lymph nodes in pediatric patients without a malignancy involving head and neck

Reza Vali, Amer Shammas, Mohammad El zein, Martin Charron
Patients and Methods

- **367** patients (882 studies) who were referred for a PET/CT study were evaluated retrospectively.

- **120** patients (316 studies) were excluded from the study due to the history of a malignancy involving H&N (e.g. thyroid cancer) or involving cervical lymph nodes at initial diagnosis (e.g. lymphoma of the cervical LN.).

- **247** patients (567 studies) without any malignancy originating from H&N region (130 lymphoma, 30 post transplant lymphoproliferative disease (PTLD) and 87 others) were included in this study.
Results

Subjects

- 247 patients
- 567 Studies

FDG activity in neck LN

- 74 Positive (29.9%)
- 83 Positive (14.6%)

- 41 Benign (39 F/U, 2 biopsy)
- 8 Malignant (1 F/U, 7 biopsy)
- 25 Not able to confirm (lack of biopsy or enough F/U or the patient was under Tx)
**Results**

- 7 out of the 8 malignant LNs were in patients with history of PTLD.

- The mean SUV-max was significantly higher in malignant lesions (5.2) compared to the benign group (2.1).

- 7 out of 8 malignant LNs had an SUV-max of more than 3 while only 3 out of 41 patients with non-malignant LNs had an SUV-max of more than 3.
Conclusion

Mild to moderate FDG uptake in cervical LNs is relatively common in pediatric patients and is frequently due to reactive LNs.

The chance of malignancy in cervical lymph node is low if the SUV-max is less than 3 with no history of PTLD.
1. Neck
2. Supraclavicular
3. Paravertebral and intercostal
4. Mediastinum
   - Tracheal and esophageal area
   - Pericardium
   - Between thoracic blood vessels
5. Perinephric and suprarenal regions
6. Anterior abdominal wall
Brown Adipose Tissue

- Generates heat in response to cold exposure
- Requires increased glucose utilization
- Sympathetic stimulation results in increased BAT utilization of glucose
  - < Benzodiazepine, propranolol, and reserpine
Brown Adipose Tissue in the Human

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</table>

- Wide distribution of active BAT in all areas of body during first decade of life
- BAT gradually disappears with advancing years

Brown adipose tissue 18F-FDG uptake in pediatric PET/CT imaging. Hong, Shammas, Charron et al: Ped Radio. 2011
Brown adipose tissue 18F-FDG uptake in pediatric PET/CT imaging. Hong, Shammas, Charron et al: Ped Radio. 2011
Brown adipose tissue 18F-FDG uptake in pediatric PET/CT imaging. Hong, Shammas, Charron et al: Ped Radio. 2011
Brown adipose tissue 18F-FDG uptake in pediatric PET/CT imaging. Hong, Shammas, Charron et al: Ped Radio. 2011
The Effect of Age on $^{18}$F-FDG Uptake in BAT

- BAT uptake more common in children than adults
  - Truong et al reported
    - 50% in children
    - 1.3% in adults
  - Yeung et al reported
    - 15% in children
    - 1.9% in adults
  - Shammas A, Lim R, Charron M. Radiographics 2009
    - 30%
- BAT uptake seen more frequently in pediatric patients older than 10 years than in those younger than 10 years
The Effect of Outdoor Temperature

- Cold exposure activates BAT thermogenesis by stimulating sympathetic nervous system

Rise in monthly incidence of uptake during winter:

Incidence: 35% January – March

20% rest of year
Brown Adipose Tissue (BAT)

Focal brown fat uptake can mimic malignancy

High incidence of $^{18}$F-FDG uptake in BAT in children makes knowledge of this potential pitfall and precise localization with PET/CT important in avoiding misinterpretation.
Reducing of $^{18}$F- FDG Uptake in Brown Adipose Tissue

- Warm environment at higher temperature than ambient hospital temperature
- Pre-medications with oral diazepam or IV fentanyl
- Use PET/CT to determine if uptake corresponds to fat or pathologic lesion on CT
- Favor Low carb diet.
Speech - perilymphgeal tissues
Uterus, Ovaries, Testes
Genitourinary

Ovary

Corpus Luteum Cyst

Ovarian uptake (inflammation with ovulation)

Normal endometrial uptake may be seen during ovulation and menstruation.
Hyperventilation
Stomach
Muscle, Growth plate

B. McCarville
Head and neck cancer

SNM Image of the Year 1999

CT: 160 mAs; 130 KVp; pitch 1.6; 5 mm slices

PET: 7 mCi FDG; 2 x 15 min; 3.4 mm slices
**Misregistration Artifact**

PET image with CT attenuation correction demonstrates uptake which appears normal on uncorrected PET image.

Fused CT and uncorrected PET shows misregistration due to head motion between PET and CT scans.
**Attenuation Artifact**

High numbers of port-a-cath overcorrect attenuation of PET data

Mimic increased uptake on PET images with CT attenuation correction

No increased uptake on images without attenuation correction

Attenuation-corrected image  Non attenuation-corrected image
Bone marrow and spleen normally show less intense uptake than the liver.

Growth Colony Stimulating Factor (GCSF) increases marrow and splenic uptake.
Benign pathologic uptake

subcutaneous injections

Multiple foci of subcutaneous uptake corresponding to CT soft tissue densities

17 year old female with history of lymphoma and history of prophylactic subcutaneous injections of Low-molecular-weight heparin
Thyroiditis
Cystic fibrosis: detecting changes in airway inflammation with FDG PET/CT

- To determine if FDG can depict a treatment effect from intravenous antibiotics for pulmonary exacerbation in cystic fibrosis (CF).
- FDG PET/CT examinations (with low-dose CT) were performed on days 1 and 14 of admission (+/- 72 hours).
- Twenty patients with CF were enrolled. Antibiotic therapy resulted in a significant decrease in SUV(max).
- Pretherapy SUV(max) and SUV(mean) and posttherapy SUV(max) were significantly different from those in control subjects.

Conclusion: FDG PET/CT is a useful tool for detecting inflammatory changes resulting from treatment for pulmonary exacerbations in pediatric patients with CF. Inflammatory changes detected by using FDG PET/CT correlated with lung function, sputum neutrophil counts, and CF-CT scores.

Amin, R... Charron, M. Cystic fibrosis: detecting changes in airway inflammation with FDG PET/CT Radiology. 2012
SUV vs Time: Dual time Imaging

- Increased FDG Uptake
  - Cancer
  - Infection
  - Inflammation
Dual-time point imaging

- Technique found to be helpful for distinguishing tumors from benign lesions in various conditions
- First scan is performed same method single-time point imaging within 1 hr of inj.
- Second scan is performed in the site of the lesion in question.
- The time interval between scans > 30 minutes
- Criterion: increase in SUV by at least 10%
Dual time-point FDG PET/CT for the evaluation of pediatric tumors

- **MALIGNANT** lesions tend to **INCREASE** in intensity between the two scans, vs. **BENIGN** lesions tend to **DECREASE** or remain stable in intensity.

12 year old male patient with neuroblastoma. Early FDG PET image shows avid FDG uptake in two liver lesions (A). Intensity of uptake was higher on delayed images (B). Corresponding coronal CT image (C).

$\text{SUV}_{\text{early1}} 9.6$
$\text{SUV}_{\text{early2}} 5.2$
$\text{SUV}_{\text{delayed1}} 15.0 \text{ (RI 56.1\%)}$
$\text{SUV}_{\text{delayed2}} 8.6 \text{ (RI 64.5\%)}$
21 patients underwent dual-time-point FDG PET/CT.

RESULTS: For patients with malignant disease, the average SUV increased from 7.3 to 10.9 between the two time points, whereas the SUV changed from 4.5 +/- 0.8 to 4.2 +/- 1.0 for patients with benign lesions.

Useful in distinguishing malignant from benign processes in pediatric patients

Costantini, D. L.Vali, R.Chan, J .McQuattie, Charron, M.
Dual-time-point FDG PET/CT for the evaluation of pediatric tumors Am J Roentgenol. 2013
Inadequate Preparation

- Patient ate meal at 7:00am
- Glucose obtained at 8:30 was 4.8mmol/L
- Patient injected at 8:50am
- Increased insulin levels leads to altered distribution of radiopharmaceutical

- PET should be performed at least 3 weeks, and preferably at 6 to 8 weeks, after chemotherapy
- 8 to 12 weeks after radiation
- Mediastinal blood pool activity is recommended as the reference background activity to define PET positivity for a residual mass > 2cm
- A smaller residual mass or a normal sized lymph node (ie, 1 x 1 cm in diameter) should be considered positive if its activity is above that of the surrounding background.
Ewing Sarcoma

- 13-year-old boy with ES STIR Images
tumor + large soft tissue mass.
- Bone scan + pelvis, femur
Ewing Sarcoma
**18F-FDG PET and PET/ CT for Detection of Pulmonary Metastases From Musculoskeletal Sarcomas. Nuclear Medicine Comm 2006 Lagaru et al.**

- **106 patients, 12 - 92 years old**
  - Liposarcoma (10 pts), Osteosarcoma (21 pts), Chondrosarcoma (6pts), Ewing's sarcoma (8pts), Leiomyosarcoma (7pts), Rhabdomyosarcoma (2 pts), MFH (20 pts) Other sarcomas (32)
- Pulmonary metastases were seen in 40 patients. CT identified 17 lesions larger than 1.0 cm, while PET identified 13 of them (76.5%).

![Graph showing sensitivity and specificity](image-url)
Prospective evaluation

- Prospective study enrolled 25 subjects 21 years old or younger with solid childhood malignancies and at least one pulmonary nodule measuring 0.5-3.0 cm

- Three panels of three reviewers each reviewed diagnostic CT only (panel 1), PET/CT only (panel 2), or diagnostic CT and PET/CT concurrently (panel 3)

- RESULTS. There were 75 nodules with a median size of 0.74 cm (range, 0.18-2.38 cm); 48 nodules were malignant.

- Sensitivity was 85% (41/48) for panel 1, 60% (29/48) for panel 2, and 67% (32/48) for panel 3. All panels had poor specificities SUVmax was a significant predictor of histologic diagnosis (p = 0.004).

- CONCLUSION. PET/CT assessment of pulmonary nodules is feasible in children with solid malignancies but may not reliably improve our ability to predict a nodule's histologic diagnosis. The SUVmax may improve the performance of PET/CT in this setting.

McCarville, M. B. (...) Shulkin, B. Am J Roentgenol. 2013 D
Neuroblastoma
Neuroblastoma

FDG  C-11 Hydroxyephedrine  C-11 Epinephrine

FDG better 2 patients, MIBG better in 3, equal 2

Shulkin BL
Post Transplant Lymphoproliferative Disease

PTLD

- Serious and potentially lethal complication of solid organ transplantation
- Ranging from Epstein–Barr Virus to aggressive types of lymphoma
- FDG-PET can visualize PTLD and is an excellent tool for staging and treatment
PTLD at Sickkids

- 17 FDG PET/CT studies in 7 patients
- The initial FDG PET/CT studies were able to identify all sites of disease noted on CT imaging and helped to clarify the equivocal findings on CT.
- During therapy, FDG PET/CT was superior to CT in detecting early response to therapy.
Post Liver Transplant PTLD

Initial scan positive

Follow up improved

5 year old female, post liver tx, PTLD biopsy positive
Skeletal PET with 18F-Fluoride: Applying New Technology to an Old Tracer: Grant F et al. JNM January 2008

- $^{18}$F-labeled NaF was the first widely used agent for skeletal scintigraphy
  - It quickly fell into disuse after the introduction of $^{99m}$Tc-labeled bone-imaging agents.
- $^{18}$F-fluoride more accurate than $^{99m}$Tc-diphosphonate SPECT
  - for identifying both malignant and benign lesions of the skeleton.
- probably will become the routine clinical practice for 18Ffluoride
16 year-old male with back pain: Interarticularis Fracture

14 year-old male with back pain: Compression Fracture
Skeletal trauma in child abuse: detection with 18F-NaF PET

Baseline skeletal survey and PET images obtained in 22 patients younger than 2 years. 14 patients also underwent follow-up skeletal survey.

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<tr>
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<th>F18-NAF</th>
<th>Skeletal survey</th>
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<tr>
<td>All Fractures</td>
<td>85%</td>
<td>72%</td>
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<tr>
<td>Thoracic fractures</td>
<td>92%</td>
<td>68%</td>
</tr>
<tr>
<td>Post.Rib Fractures</td>
<td>93%</td>
<td>73%</td>
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<tr>
<td>Methapyseal lesions</td>
<td>67%</td>
<td>80%</td>
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</table>

18F-NaF PET had greater sensitivity in the overall detection of fractures related to child abuse particularly in ribs.

Radiology, 2010;255.
Infants with congenital hyperinsulinism may have either focal or diffuse abnormalities of the pancreatic β cells. Focal Vs diffuse
Fig. 2. Metabolic pathways. In this figure the different metabolic pathways by which neuroendocrine tumors can be visualized using nuclear medicine imaging techniques are schematically depicted. Three major routes can be identified: receptor-based techniques, techniques which use the metabolic properties of these tumors and labeled antibody-based techniques.
$^{177}\text{Lu-DOTA-TATE}$

$^{131}\text{I-MIBG}$

Somatostatin receptor

Noradrenaline Transporter
High energy photons escape the body for PET imaging.

1899 keV β+ positron

511 keV, γ–photon

511 keV, γ–photon

490 keV β– electron

High energy electrons deposit energy in tissue for therapy.
Yesterday

• Orphan status awarded for gallium-68 DOTATATE

**Orphan status awarded for gallium-68 DOTATATE**
Advanced Accelerator Applications' gallium-68 DOTATATE, a radiopharmaceutical used in PET/CT imaging of gastro-entero-pancreatic neuroendocrine tumors, has been granted orphan drug status by the FDA and the European Medicines Agency. Preliminary data suggest the agent will improve cancer diagnosis while reducing radiation exposure.
Carbon-11 Methionine PET/CT imaging of pediatric sarcomas

- 8 Pts. (osteosarcoma, rabdo, Ewing and liposarcoma)
  - 7/8 were positive.

- In 4 cases $^{11}$C Methionine was more intense than F18-FDG

- In those Pts with pre- & post- therapy scans, C11-meth. and F18-FDG showed reduced uptake with treatment.

Shulkin et al. J Nucl Med. 2010; 51,
FLT-PET: Imaging of Proliferation

- FLT - 3’-deoxy-3’-\([^{18}\text{F}]\)-fluorothymidine
- Analogue of thymidine
- Marker of cellular proliferation (vs. FDG - glucose analogue / marker of metabolism)

1) Salskov, Semin Nucl Med, 2007
FLT PET Case - 11 year old body with a germ cell tumor of the basal ganglia

Uptake of FDG masked by normal grey matter uptake

- FLT-PET reveals hypermetabolic foci suggesting the presence of a malignant tumor

Choi et al, Eur J Nucl Med Mol Imaging, 2005
• CTA to study FLT-PET in paediatric patients with HL
• Can FLT PET help distinguish benign from malignant disease in patients with equivocal FDG PET findings?
12-year old patient with increased widening of mediastinum after completion of therapy and suspected new lymph node in anterior mediastinum on CT scan.
F18- FLT didn't show any definite focus of increased uptake in the anterior mediastinum
### PET Radiopharmaceuticals
#### Oncology: NEJM

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<th>Radiopharmaceuticals</th>
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<td>$^{11}$C-thymidine</td>
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<td>Tissue hypoxia</td>
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<td>$^{18}$F-fluorothymidine</td>
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<tr>
<td>$^{11}$C-methionine</td>
<td>Protein synthesis, tumor-cell proliferation</td>
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<td>$^{11}$C-choline</td>
<td>Cell-membrane metabolism, tumor-cell proliferation</td>
<td>Apoptotic cell death</td>
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<td>$^{11}$C-acetate</td>
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Functional Imaging
Paragangliomas

- 10 Pts. with 26 parangangliomas: J Clin Endocrinol Metab 2011
- 26/26: [(18)F-fluorodihydroxyphenylalanine : 18F-FDOPA
- 20/26: (18)F-fluoro-2-deoxy-D-glucose : 18-FDG
- 16/25: (111)In-pentetretotide
- 12/26: (18)F-fluorodopamine : 18F-FDA
- 8/26 (123)I-metaiodobenzylguanidine : 123I-MIBG

- 216 pts w Pheo or Paraganglioma J Natl Cancer Inst. 2012
  - Compared with (123)I-MIBG SPECT and CT/MRI, both considered gold standards, metastases were better detected by (18)F-FDG PET
Neuro-Normal

Caudate (curved arrows)
Thalami (long arrows).

Optic nerves (arrowheads)
Temporal lobes (straight arrows)
Cerebellum (curved arrows).

Waldeyer ring (arrowheads)
parotid glands (arrows)
Right mesial temporal lobe sclerosis

MRI and PET images show reduction in FDG corresponds to the region of MRI increase in signal intensity in the right mesial temporal lobe (hippocampal region).
4 year-old girl with intractable seizure, MRI on Feb, 2011 was normal, MRI on March, 2012 showed diffusely increased signal intensity in the left temporal pole; diffuse cortical dysplasia.
Epilepsy/HSC

- Evaluate sensitivity, specificity, of FDG-PET, MEG, FDG-PET + MEG, and FDG-PET/MEG in children with nonlesional localization-related epilepsy.
- METHODS: Twenty-six children underwent FDG-PET and MEG.
- Twenty-two patients had surgical resection, and surgical outcome was assessed using Engel classification.
- There was no significant difference between MEG and FDG-PET for concordance with surgical resection.
- SIGNIFICANCE: The two tests FDG-PET and MEG were complementary in the assessment of children with localization-related epilepsy, particularly when one test was nonlocalizing or nonconcordant.

Dopaminergic Neurotransmission

- **11C-L-Deprenyl**
- **11C-Clorgyline**
- **18F-DOPA**
- **11C-WIN 35428**
- **11C-Raclopride**
- **H215O**
- **18FDG**

**Presynaptic Neuron**

- Tyrosine
- L-DOPA
- AADC
- MAO-A
- MAO-B
- DAT
- D1
- D2
- D3
- cAMP
- COMT

**Postsynaptic Neuron**

**SIGNAL**

**Glia Cell**

Designed by V Villemagne, MD
Neurotransmitter Imaging
Dopamine

D2 receptor antagonist: 11C-raclopride
Striatum in a healthy volunteer
(A. fischman)
Neurotransmitter Imaging
Dopamine Transporter (DAT)

- 11C-altropane (Fischman et al.)
Neurotransmitter Imaging: Dopamine

Changes in the rate of displacement of 11C-raclopride in the left putamen during a motor planning task in healthy volunteers. Vertical lines indicate the time of task initiation.
Anomalous Origin Of The Left Coronary Artery Arising From The Pulmonary Artery

- Fixed defect AL corresponds to an acute myocardial infarction (Courtesy of Dr. Heinrich Schelbert, David Geffen School of Medicine, Los Angeles.)
Transposition of the great arteries after the arterial switch operation.

- Impaired perfusion AL wall
- FDG is preserved: Viable Myocardium
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<th>Infections</th>
<th>Inflammatory/granulomatous</th>
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<td>Hodgkin’s disease</td>
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<td>Pneumonia</td>
<td>Wegener’s granulomatosis</td>
<td>Non-Hodgkin’s lymphoma</td>
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<tr>
<td>Osteomyelitis</td>
<td>Sarcoidosis</td>
<td>Colon carcinoma</td>
</tr>
<tr>
<td>Vascular graft infection</td>
<td>Thyroiditis</td>
<td>Renal cell carcinoma</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>Myositis</td>
<td>Sarcoma</td>
</tr>
<tr>
<td>Sinusitis</td>
<td>Gastritis</td>
<td>Pheochromocytoma</td>
</tr>
<tr>
<td>Mastoiditis</td>
<td>Giant cell arteritis</td>
<td></td>
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</tbody>
</table>
Studies FDG-PET and FUO

- PET helpfulness in the diagnosis of FUO reported in 5 recent studies: 37% to 69%
  - slightly different definition of FUO, heterogeneous disorders, variable FDG-PET techniques, and no structured diagnostic protocol

- FDG was more helpful in patients with a suspected focal infection or localized inflammation than in FUO
  
  *Bleeker-Rovers* *Eur J Nucl Med Mol Imaging* 2004

- 30 patients PET contributed to the diagnosis in 71% of the cases. *Zhuang et al.*

Positive Lymph nodes patient FUO
The patient was diagnosed with Hodgkin’s disease
H. Zhuang
IBD

- PET helpful to assess disease activity *Bicik Lancet 1997*

- 18 children Ss and Sp 81% and 85% *Skehan Lancet 1999*

- Physiologic Bowel FDG activity, affect the SS/SP of PET

- Uptake colon common in patients without IBD

- Irregular or focal intense uptake reported in asymptomatic patients *Kim S, Clin Positron Imaging 1999.*

- Drugs with antiperistaltic effects (atropine sincalide) has not shown any difference in five young volunteers *Jadva Clin Nucl Med 1999;24*
WBC HMPAO $^{99m}$Tc

- 30 min: 8 min AP
- 2-3 hr: 8 min AP
  SPECT
Late Physiological Accumulation

1) none at 30 minutes
2) Faint (<= iliac crest)
3) Diffuse
4) Other segments NI
5) Migration with time
lymphoscintigraphy

- We identified 56 patients (33 patients with melanoma and melanocytic lesions, and 23 with sarcomas).
- Of 58 lymphoscintigraphy procedures, sentinel lymph nodes were identified in 52 (90% success rate). Using the combination of intraoperative blue dye injection and lymphoscintigraphy, the success rate was 95% (55/58).
- Metastatic disease was found in 14 sentinel lymph nodes.
- CONCLUSION: lymphoscintigraphy with SLNB is an effective method to identify patients who may benefit from more extensive lymph-node dissection and to identify those patients who are unlikely to benefit from further lymph-node exploration.

Parida, L… Shulkin, B. L. Pediatr Surg Int. 2012 J
11 MONTH OLD GIRL WITH FEVER
Pyelonephritis?

1. Yes
2. No
3. Maybe
4. I wish I knew!
5. Small left kidney
1. Yes
2. No
3. Maybe
4. I wish I knew!
5. Small left kidney
Normal Scan

- Cortical uptake homogenous, with normal contours
- Photopenic areas adjacent to pelvis with normal outline
- Flattening superolateral aspect of left kidney
Pyelonephritis
Scarring
Pinhole = Variable Magnification
Imaging Studies after a First Febrile Urinary Tract Infection in Young Children

Alejandro Hoberman, M.D., Martin Charron, M.D., Robert W. Hickey, M.D., Marc Baskin, M.D., Diana H. Kearney, R.N., and Ellen R. Wald, M.D.
METHODS
In a prospective trial involving 309 children (1 to 24 months old), an ultrasonogram and an initial renal scan were obtained within 72 hours after diagnosis, contrast voiding cystourethrography was performed one month later, and renal scanning was repeated six months later.

RESULTS
The ultrasonographic results were normal in 88 percent of the children (272 of 309); the identified abnormalities did not modify management. Acute pyelonephritis was di-

CONCLUSIONS
An ultrasonogram performed at the time of acute illness is of limited value.
Imaging Studies for Childhood Urinary Infections
F. Bruder Stapleton, M.D.

A first urinary tract infection. The controversy concerning the routine use of dimercaptosuccinic acid scintigraphy in either the short-term or the long-term follow-up of young children with a first febrile urinary tract infection is not addressed in the study prenatal ultrasonography. Renal ultrasonography continues to be a safe and relatively cost-efficient means of assessing the anatomical features of the upper urinary tract, when the clinical situation demands this information. A urinary tract infection during the first two years of life may no longer be included in this category of conditions.
Diagnostic criteria for obstruction: not validated

- Clearance half-time ($T_{1/2}$)
  - Value $>20$ m.: Suggestive (not indicative) of obstruction
  - 10 to 20 m.: indeterminate
  - $<10$ m.: obstruction very unlikely
Causes of Indeterminate (or F+) Results

- Impaired renal function
- Markedly dilated renal collecting system
- Ureteral reflux
Impaired Function
Marked Hydronephrosis
Obstruction
Indirect VCUG
Neuroblastoma
MIBG-131
Dx Dose
Neuroblastoma
MI BG-131
Tx Dose
Aspiration- Salivagram

- A small drop saline with 1 mCi $^{99mTc}$ is placed on the tongue
  - Concentration ~ 300 times higher
- Images are obtained for ~10 min
Gastric Emptying And Reflux

- Gastric Emptying 40 to 70% at 60 min
- Number of episodes of reflux, level reached, and the clearance rate are noted
Milk Scan Vs. PH probe

- Milk Scan offers information that the PH probe doesn’t.
  - Gastric emptying in %
  - Detect non-acidic reflux
    - 16% children had predominantly alkaline reflux*
  - Detects aspiration

J Ped Surg 1991